

UNITED STATES PATENT APPLICATION

Of

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For

A SINGLE TRANSFORMER HYBRID SYSTEM AND METHOD

PRIORITY

This application claims priority to U.S. Provisional Patent Application Ser. No. 60/445,022 filed February 5, 2003.

5 BACKGROUND

The invention generally relates to transformer systems, and relates in particular to transformer hybrid systems for use with modem systems.

Many modem systems include a hybrid matching network to facilitate the transmission of a signal, to permit reception of a signal with reduced attenuation, and to reduce interference from
10 the signal transmission path into the signal reception path. The hybrid matching network provides the interface between the modem circuit and the transmission line, e.g., the tip and ring of the telephone network. The hybrid network, therefore, must properly terminate the transmission line.

In particular, many conventional hybrid networks employ a transformer to provide the
15 required isolation barriers between sensitive electronic circuitry and the telephone line. This transformer is also used to step the transmit (TX) voltage up or down depending on the application. The hybrid network may also properly accept the receive (RX) signal while keeping the TX signal from entering the RX path and contaminating the RX signal (e.g., with an echo signal).

20 As shown in Figure 1, a conventional hybrid matching network may include a pair of transmit differential signal nodes 10, 12, a pair of receive differential signal nodes 14, 16, and transmit line differential signal nodes 18, 20 for coupling to the tip and ring of a telephone

network. The circuit also includes a balanced Wheatstone bridge including windings (N1) 22, 24 on the integrated circuit side and impedances (Z_m) 26, 28 and further includes windings (N2) 30, 32 on the line side. Ideally, impedances (Z_m) 26, 28 are chosen to be identical to the reflected line impedances as seen through the N1 windings. Half of the TX signal, therefore, is dropped across each of the N1 windings. The total voltage across the two N2 windings is the TX signal multiplied by the turns ratio $N2/N1$. The turns ratio may, therefore, be used to control any stepping up or down of the TX signal.

The transmit differential signal nodes 10, 12 should effectively appear to be ground to the RX signal. Each of the N1 windings sees half of the RX signal reflected by the turns ratio. The complete reflected RX signal, therefore, appears at the receive differential signal nodes 14, 16.

The interference rejection (echo rejection) is achieved by employing a balanced bridge such that no component of the TX signal appears at the receive differential signal nodes 14, 16. The closer that the impedance Z_m is matched to the line impedance reflected through the N1 windings, the better the circuit will provide echo rejection. The telephone line may typically be modeled with an RC circuit, although it is sometimes helpful to also include an inductor in Z_m to match the effect of the transformer inductance. The use of inductors in the matching network, however, is not generally desired due to their size, cost and/or noise sensitivity. The matching impedance Z_m , therefore, is typically implemented using only resistors and capacitors, and the hybrid matching is typically optimized for a specific desired frequency range.

In certain applications, the swing range of the TX signal may not be large enough to provide the desired voltage to nodes 18 and 20. If a transformer is used to step the TX voltage up on the line side, then the value of the capacitors in Z_m may become too large and/or

expensive. For example, a three-fold increase in the turns ratio (e.g., from 1:1 to 1:3) may require a nine fold increase in the size of the required capacitance in Z_m .

There is a need, therefore, for more efficient and cost effective implementation of a hybrid matching network.

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SUMMARY OF THE INVENTION

In accordance with an embodiment, the invention provides a hybrid matching system for use with a transmitter and receiver. The hybrid matching system includes a pair of transmitter output nodes, a pair of receiver input nodes, and a pair of line terminals for communication with the transmission line. The system further includes a first impedance bridge portion including at least one inductor for coupling to the line terminals via at least one transformer winding, and a second impedance bridge portion interposed between the pair of transmitter output nodes and the first impedance bridge portion, and interposed between the pair of receiver input nodes and the first impedance bridge portion

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BRIEF DESCRIPTION OF THE DRAWINGS

The following description may be further understood with reference to the accompanying drawings in which:

Figure 1 shows a diagrammatic illustrative view of transformer bridge hybrid circuit of the prior art;

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Figure 2 shows a diagrammatic illustrative view of transformer bridge hybrid circuit in accordance with an embodiment of the invention; and

Figure 3 shows a diagrammatic illustrative view of transformer bridge hybrid circuit in accordance with another embodiment of the invention.

The drawings are shown for illustrative purposes only.

5 DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

As shown in Figure 2, a hybrid matching network in accordance with an embodiment of the invention further includes a supplemental matching network 34 and a receive path coupling network 36. In the embodiment shown, the supplemental matching network 34 includes a pair of impedances (38, 40) of value kZ_m and a pair of impedances (42, 44) of value kZ_r , where Z_r is
10 the reflected line impedance to each primary winding of the transformer. The receive path coupling network 36 includes a first summer 46 that is coupled to a node A in the main bridge via an amplifier 48 (having a gain of G_1) and is coupled to a node C in the supplemental bridge via an amplifier 40 (having a gain of G_2). The receive path coupling network 36 further includes a second summer 52 that is coupled to a node B in the main bridge via an amplifier 54 (having a
15 gain of G_1) and is coupled to a node D in the supplemental bridge via an amplifier 56 (having a gain of G_2). The outputs of the summers 46, 52 provide the differential receive signal at nodes 14 and 16 respectively.

In this new scheme, the impedance Z_m is not required to be an exact match of the reflected line impedance, and the bridge that includes the N_1 transformer windings is not
20 required to cancel the entire TX signal. The impedance Z_m may simply be a termination impedance for the transmission line. For the echo rejection, the supplemental matching network 34 is employed, and its signal is added to the signal of the main bridge. In the embodiment

shown in Figure 2, the supplemental bridge has the same impedances that exist in the main bridge, with Z_r being the same as the reflected impedance seen through $N1$. The phasing of the bridge signals is chosen such that they are equal and opposite of each other.

The voltage difference between the voltages at node A and node B (V_{AB}) will be equal to
5 the negative of the voltage difference between the voltages at node C and node D (V_{CD}), i.e., $V_{AB} = -V_{CD}$, and adding the two bridge outputs together (with $G1=G2$) will provide sufficient echo rejection. In fact, for V_{AB} and V_{CD} to have the same magnitude, the impedances in the 4 branches of the supplemental bridge need only be scaled versions of the corresponding branches of the main bridge. This means that the factor k may have a range of values, and there exists
10 considerable freedom in choosing components that provide the impedances Z_m , kZ_m and kZ_r . In a general form, the four impedances in the supplemental bridge may be any value as long as V_{CD} is a scaled replica of V_{AB} but with opposite polarity. The gains $G1$ and $G2$ may then be chosen to cancel the outputs of the two bridges.

For example, as shown in Figure 3, a specific implementation of an embodiment of the
15 invention may include the use of a combination of resistors and capacitors for the impedances 38, 40, 42 and 44. In particular, the impedances 38 and 40 may each include a resistor 60 (e.g., having a value of 24.9Ω) in parallel with a capacitor 62 (e.g., having a value of 1.5 nF). The impedances 42 and 44 may each include a resistor 64 (e.g., having a value of $1.91 \text{ k}\Omega$) in parallel
20 with a capacitor 66 (e.g., having a value of 33 nF), each of which is also in series with another resistor 68 (e.g., having a value of 27.4Ω).

The two bridge outputs may be added to one another in a variety of ways. The receive path coupling network for the positive receive differential signal node 14 includes a resistor 70

(e.g., having a value of $50\ \Omega$) that is coupled to node A in the main bridge, and a resistor 72 (e.g., having an value of $100\ \Omega$) that is coupled to node C in the supplemental bridge. The signals from each resistor 70 and 72 are combined (or summed) at node 74 as shown. The receive path coupling network for the negative receive differential signal node 16 includes a resistor 76 (e.g.,
5 having an value of $50\ \Omega$) that is coupled to node B in the main bridge, and a resistor 78 (e.g., having an value of $100\ \Omega$) that is coupled to node D in the supplemental bridge. The signals from each resistor 76 and 78 are combined (or mixed) at node 80 as shown. The receive path signals are added, therefore, using summing resistors. This leads to RX signal attenuation by a factor of $2/3$ in that the points 14 and 16 provide a resistor-divided version of the full RX signal.
10 The circuit in the supplemental bridge has been designed such that the magnitude of V_{CD} due to the Tx signal is about two times the magnitude of V_{AB} due to the Tx signal. The resistors 72, 78 that carry the output of the supplemental bridge are twice as large as the resistors 70, 72 that carry the output of the main bridge, and the RX signal attenuation is, therefore, decreased. Because resistors are used in this embodiment for the gains $G1$ and $G2$, these paths are frequency
15 independent. In other embodiments, any combination of amplifiers, resistors, capacitors and/or inductors may be used to achieve a variety of characteristics of these receive signal networks.

The impedances 26, 28 may be chosen to be simply resistors 82. By making the Z_m blocks resistive rather than complex (resistive / capacitive / inductive), more power may be transferred to the tip (18) and ring (20) for a given TX signal strength. An additional capacitor
20 84 may be employed between the N2 windings 30, 32 as required in various applications to block DC signals. The impedances in the supplemental bridge have been optimized above to achieve efficient hybrid rejection while eliminating inductors and minimizing capacitor values.

The total value of capacitance of each leg of the supplemental bridge above is only 34.5 nF, whereas the total value of capacitance for a comparable circuit of Figure 1 may be more than tens times larger (e.g., 370 nF).

Those skilled in the art will appreciate that numerous modifications and variations may
5 be made to the above disclosed embodiments without departing from the spirit and scope of the invention.

What is claimed is: